SYSTEM REQUIREMENTS DEFINITION DOCUMENT

APPENDIX D

FINAL REPORT
IMPROVED ORBITER WASTE
COLLECTION SYSTEM STUDY

NAS 9-17181

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

ORBITER FECES COLLECTION REQUIREMENTS OUTLINE

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ORBITER FECES COLLECTION REQUIREMENTS

Ref. Doc.,Pg.

1. GENERAL PURPOSE

1.1 Scope

This System Requirements Definition Document establishes basic requirements for a Space Shuttle Orbiter Waste Collection System and is intended to be an aid in the development and procurement of a representative flight test article.

1.2 General Requirements

1.2.1 The WCS shall collect, process and store Feces, Vomitus and Paper

1.2.2 The WCS shall eliminate Problems Experienced on Existing Orbiter System

1.2.3 The WCS shall be retrofittable into Orbiter Structure and Interfaces

2. APPLICABLE DOCUMENTS

	Abbreviation	Keyword	Title
2.1	M	MDAC	MDAC proposal for Space Shuttle Orbiter Waste Collection System (WCS) Study, Volume 1, Technical Proposal, MDAC Report MDC H1157, May 1984.
2.2	R	Rockwell	Rockwell Waste Collection Subsystem Procurement Spec. No. MC282-0069, Rockwell International, 1-24-83.
2.3	F	Flight Operations	Shuttle Flight Operations Manual, SFOM Volume 12, NASA/JSC, 5-13-83.
2.4	U	Urine Collector	Orbital Workshop Centrifugal (Urine) Separator System CDR Data Pakcag;e, MDAC Report, 3-31-71.

Ref. Doc.,Pg.

Specific requirements found in this document are referenced as to their source, when applicable, according to the following system:

Reference Document, Page

Example: R8
Indicates source document R, Page 8.

3. ORBITER INTERFACE REQUIREMENTS

3.1 General Requirement

The collector assembly shall contain the fecal waste collector, urine collector assembly, all control valving, instrumentation, interconnecting plumbing and mounting framework. R8

3.2 Structural

3.2.1 Envelope Dimensions:

Be retrofittable within current system compartment into the Orbiter fleet in the field (Figure 1). M5

3.2.2 Utilize existing supports and mounts when possible.

3.2.3 Utilize physical interfaces with existing urine collection system

3.2.4 Utilize physical interfaces with existing airflow source

3.2.5 Requirement for Support of Existing Pump/Fan and Filter (TBD)

3.3 Electrical

3.3.1 Switching for Existing Pump/Fan (TBD)

3.3.2 Switching for Bag Heat Sealing as Required (Skylab type) (TBD)

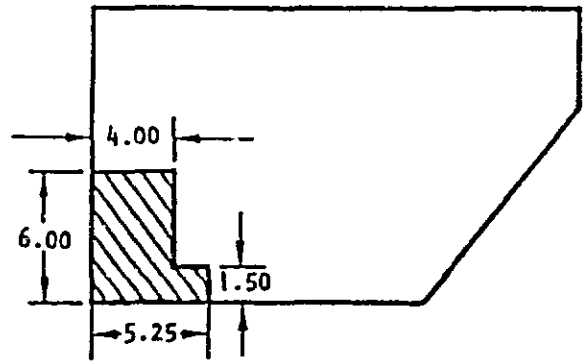
3.4 Gas/Liquid

3.4.1 Ports: The WCS port interface sizes are defined in the schematic of Figure 2. R7

3.4.2 Fluids: Procurement and use of fluids shall be controlled to the extent specified in SE-S-0073. R7

TOLERANCES EXCEPT AS NOTED:
ANGLES ± 30'
DECIMALS: .XX = ± 0.03
.XXX = ± 0.010

NOTE:
THE ENVELOPE DOES NOT INCLUDE FOOT RESTRAINTS WHICH MAY EXTEND INTO THE ACCESS AISLE WHEN THE WCS IS IN USE.



VIEW A-A LOOKING AFT

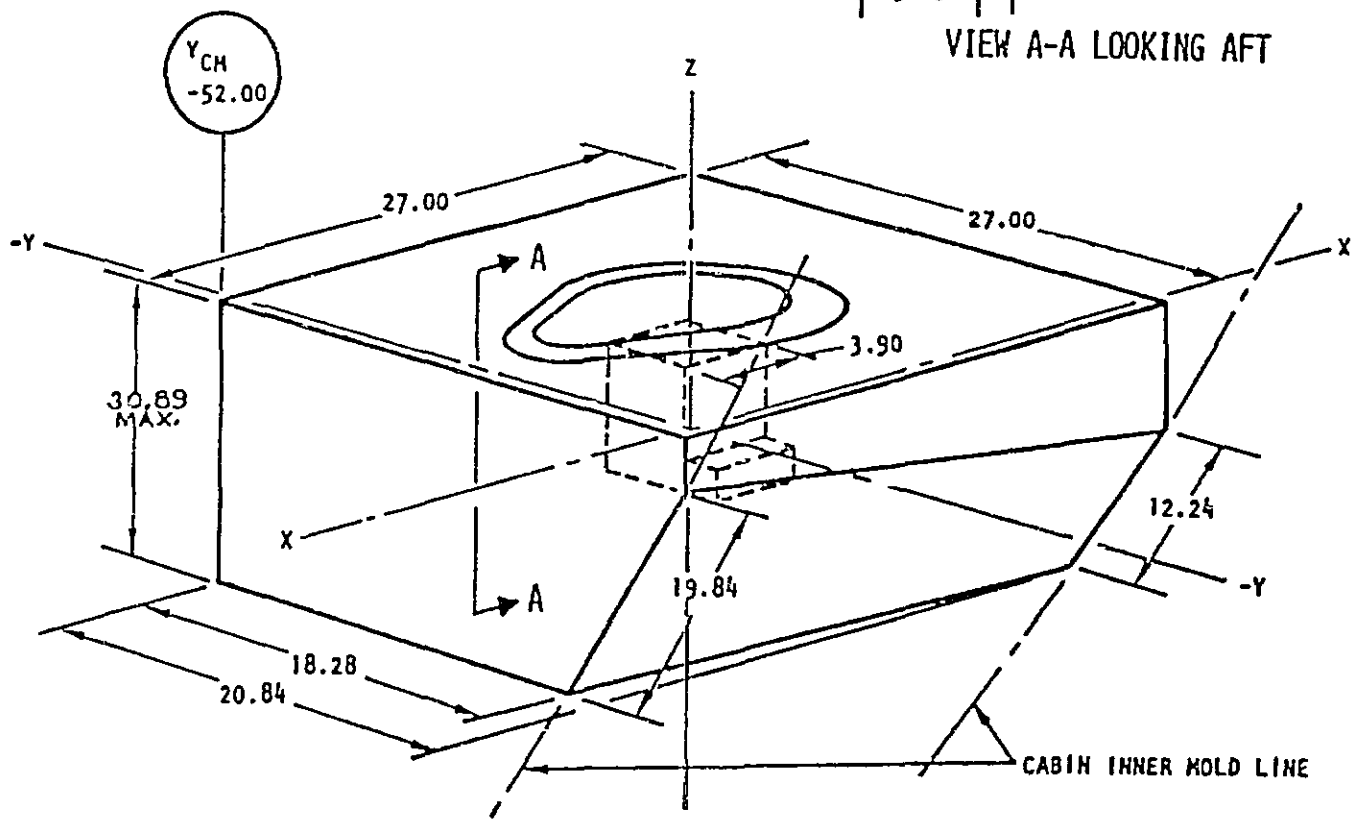


Figure 1. Waste Collector Subsystem Envelope

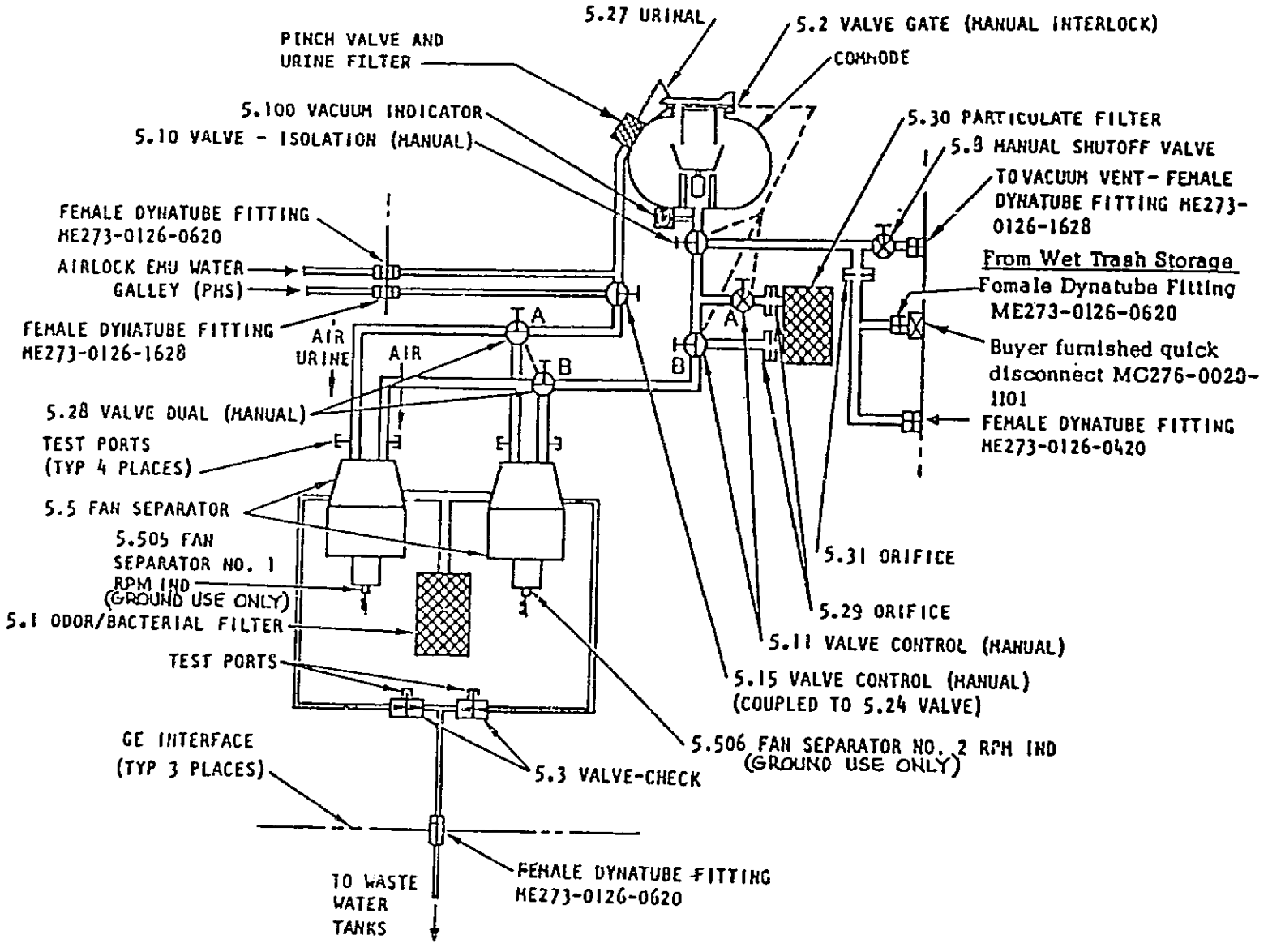


Figure 2. Waste Collector Subsystem Schematic (SAMPLE)

Ref. Doc.,Pg.

3.4.3 There will be no water flush in the fecal waste or urine collection systems. R5

3.4.4 Airflow Available from Existing Pump/Fan:

- Commode: 30 ft^3/min (0.85 m^3/min) F3.19-48
- Urinal: 8 ft^3/min (0.23 m^3/min)

3.4.5 Vacuum Available for Processing:

All portions of the assembly exposed to space vacuum shall withstand at least 16.0 psia cabin pressure without damage. R8

3.5 Odor/Microbiological Contamination

3.5.1 Include a filter for bacteria and odor control having the following characteristics:

- The capability of filtering contaminated air from the WCS at a flow rate of 38 scfm. P9
- The capability of operating in a maximum pressure of 16 psia. R9
- The capability of operating at an air flow rate of 38 scfm. R9
- A pressure drop across the filter not exceeding 2.35 inches of water at a 38 scfm air flow rate. R9
- The capability of removing 99.999 percent of all particles 0.45 microns or larger. R9
- The capability of supporting a minimum differential pressure of 1.0 psi. R9
- A total weight of 7.5 pounds or less. R9
- An operating range of 14.7 + 0.2 psia (1034 + 14 g/cm^2).
- A maximum ΔP of 1 in. H_2O (25.4 mm H_2O).
- A filter medium consisting of activated charcoal.
- An operating temperature range of 65^0 to 90^0F F3.19-46

3.5.2 The assembly shall remove bacteria, vomitus, trash, urine and fecal odors, skin, hair and other body particles from the entrainment air before returning it to the cabin. R8

Ref. Doc.,Pg.

3.5.3 Porous filter media shall be rated for removal of 99.999 percent of all particles above 0.45 μm and have hydrophobic characteristics.

3.6 Bag Stowage Space Availability - Fresh and Used
Subject to structural envelope and selected configuration.

3.7 Processor Space Envelope
Subject to structural envelope and selected configuration.

4. PERFORMANCE REQUIREMENTS

4.1 Collection
The WCS shall meet criteria as outlined in Sections 4.1.1 through 4.1.13.

4.1.1 Provide for collecting, storing and deactivating fecal wastes and associated toilet paper for a minimum of 56 man-days of use. R5

4.1.2 Provide for collecting wash water from the galley. R5

4.1.3 Provide for collecting Extravehicular Mobility Unit (EMU) water from the airlock. R5

4.1.4 Provide for transferring the collected fluids to waste storage tanks. R5

4.1.5 Provide for draining air and vapors from the wet trash storage compartment. R5

4.1.6 Provide for no contamination of crew or crew compartment by system.

4.1.7 Effectively and hygienically separate wastes from the crew member. M4

4.1.8 Airflow will be used for directional control of the fecal waste and for urine entrainment during zero-g operations. R5

4.1.9 Provide for 13" bolus accommodation.

	Ref. Doc.,Pg.
4.1.10 Provide for a nominal quantity of - Water: 0.2 lb/man-day (0.09 kg) - Solids: 0.27 lb/man-day (0.12 kg) - Paper: TBD	F3.19-45
4.1.11 Provide for quantity range of - Water: 0.13 to 0.44 lb/man-day (0.059 to 0.20 kg) - Solids: 0.04 to 0.15 lb/man-day (0.018 to 0.068 kg) - Paper: TBD	
4.1.12 Maximum commode usage will be four defecations per hour.	R8
4.1.13 Number of Fresh Bags, Wipes Required (TBD)	

4.2 Processing

4.2.1 Fecal waste will be deactivated by exposure to space ambient.	R5
4.2.2 Time for Processing (TBD)	
4.2.3 Temperature Requirements (TBD)	

4.3 Vacuum Requirements

4.3.1 Interlocks shall be provided which prevent vacuum venting prior to closure and sealing of the processing area.	R9
4.3.2 Provisions shall be made to prevent particulate waste carry-over during vacuum deactivation.	R8
4.3.3 Vacuum Vent Requirement: - Number: 1 - Operating pressure range: 0 to 14.9 psia (0 to 1048 g/cm^2) -ΔP: 14.7 to 0.2 psia (1034 to 14 g/cm^2)	F3.19-46

4.4 Storage

4.4.1 Provide for stowage of fresh bags, wipes, etc. for a 56 man-day mission + contingency supplies + spares	
4.4.2 Provide for stowage of used bags and wipes, etc. for a 56 man-day mission	
4.4.3 Store the wastes in a safe, odorless form separate from the crew compartment.	M4

	Ref. Doc., Pg.
4.5 Weight.	
The weight of the WCS shall not exceed TBD pounds, not including expendables.	R10
4.6 Life Cycle	
4.6.1 Operating Life - As a design objective, the WCS static components shall be capable of performing all operations specified herein for a minimum of TBD hours.	R8
4.6.2 Useful Life - As a design objective, the WCS shall have a minimum useful life of TBD hours, which are equivalent to TBD orbital missions in a 10-year period from date of delivery. The average orbital mission will be 7 days.	R8
4.6.3 Shelf Life - As a design objective, the WCS shall be capable of operating in accordance with the requirements specified herein any time within a period of TBD years from date of delivery when exposed to the environment discussed in environmental requirements.	R8
5. FLIGHT CREW OPERATIONAL REQUIREMENTS	
5.1 Time Required for Operation: The WCS shall accommodate four usages per hour, i.e., 15 min/cycle.	R8
5.2 Flight Crew Procedures (Commode Operations, Etc.)	
5.2.1 The WCS shall be simple in use, straightforward, and not take excessive time.	M4
5.2.2 The WCS shall require only minimal training for successful crew use.	M4
5.2.3 Fecal waste will not be handled directly by the crew.	R5
5.2.4 It shall be possible to use the urine collector assembly independently of the fecal waste collector.	R9

	Ref. Doc., Pg.
5.3 Crew Physical Interfaces	
5.3.1 The WCS shall provide adequate body stabilization for use.	M4
5.3.2 The WCS shall accommodate use by both male and female.	M4
5.3.3 Urine collection interface shall be individual.	M4
5.3.4 Foot and body restraints which facilitate usage of the assembly while the orbiter is performing space operations shall be provided. The foot support shall include foot restraints and shall be adjustable. Toe restraints shall be provided. The body restraint system shall retain the crew person in the proper location and position.	M4 R9
5.3.5 Arrangement of manually controlled valves and devices and nomenclature shall facilitate operation of the assembly.	R9
5.3.6 Surface Finishes - All exterior surfaces of the WCS, except the seat, shall be TBD in color. The seat shall be TBD in color. All surfaces of the WCS that require paint shall receive a primer coat of TBD	R9
5.4 Controls and Display	
5.4.1 A mechanical device shall be provided to warn/prevent switching the liquid waste control switch from the "PHS/EMU" position when the EMU condensator in the airlock is being dumped. The device shall have nomenclature identifying its use.	R9
5.4.2 Nomenclature and Markings - The WCS nomenclature and markings shall be in accordance with MF0004-019. The wet trash storage vent disconnect shall have the designation "80V62TP126" and the nomenclature "VAC VENT" marked directly above it.	R10

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Ref. Doc., Pg.

5.4.3 Human Performance/Human Engineering - The design shall consider the capabilities and limitations of the human operator wherever a man-machine interface exists, including torques, forces, and other functional design characteristics of controls, displays, and work stations. The principal design guide for the man-machine interface shall be MIL-STD-1472. R24

5.5 Noise Level

5.5.1 Acoustical Noise - The WCS equipment shall not generate noise in excess of the following sound pressure levels (SPL) at the associated octave band center frequency (OBCF) during operation with the seat valve open and closed. Noise level microphones shall be three feet from the test unit at four locations ninety degrees apart around the unit. (SPL values include ambient background noise corrections). R24

Max. SPL (dB re 20μN/m^2)	OBCF(Hz)
58	63
66	125
70	250
69	500
71	1000
64	2000
64	4000
56	8000

5.5.2 The WCS shall be quiet during operation and not disturb sleep (Goal: Noise Criteria [NC] 40). M4

5.6 Safety

The design and operation shall comply with the following safety requirements:

5.6.1 All handholds and handrails shall provide a minimum clearance of 2.0 inches between the gripping surface and any adjacent structure and provide a minimum of 5.5 inches of straight grasping surface. R23

	Ref. Doc.,Pg.
5.6.2 Equipment shall revert to a safe configuration when an input power loss occurs.	R23
5.6.3 All materials including seals, gaskets, and lubricants shall be compatible with the service commodity.	R23
5.6.4 Lines shall be firmly supported and shall be independently clamped or supported.	R24
5.6.5 All pressure vessels and reservoirs shall have an isolation shutoff valve located at the first component downstream of the vessel and as close as possible to the vessel.	R24
5.6.6 Filters shall be replaceable without requiring removal of filter housing, and shall be designed such that bacteria is prevented from escaping during filter replacement, and such that the crew is sanitarily protected.	R24
5.6.7 All mechanical actuating devices shall have positive mechanical stops.	R24
5.6.8 Access doors or covers which are not removable shall be self supporting when open.	R24
5.6.9 All fan blades, pump impellers and similar rotating mechanisms shall have protective devices such as a shear pin, friction clutch, magnetic clutch or a similar device to protect the drive mechanism.	R24
5.6.10 Equipment utilizing rotating mechanisms shall incorporate provisions for containment of failed parts. Lock or latching mechanisms shall be operable by a single control and provide clear visual indication of latch position.	R24
5.6.11 Controls shall be designed and located to minimize inadvertent activation.	R24

Ref. Doc., Pg.

5.6.12 Material which can shatter shall not be used unless positive protection is provided to prevent fragments from entering cabin environment or striking personnel. R24

5.6.13 Exposed sharp surfaces or protrusions shall be eliminated. R24

6. GROUND OPERATIONAL REQUIREMENTS

6.1 General Requirements:

6.1.1 The WCS shall be maintainable at the launch site, requiring minimal turnaround time/impacts. M5

6.1.2 The WCS shall have the capability for in-vehicle turnaround.

6.2 Ground Equipment for Bag and Supply Handling

6.2.1 Provide for larger bags or lockers to transfer fresh and used waste collection bags.

6.2.2 Vehicle requirement (TBD)

6.2.3 Manpower requirement (TBD)

6.3 Ground Equipment for System Maintenance - As required for selected configuration.

6.4 Ground Handling Maintenance Procedures - As required for selected configuration.

6.5 Preflight Checkout and Preparation (TBD)

7. FLIGHT ENVIRONMENTAL REQUIREMENTS

7.1 Operational Flight Environment

Ref. Doc., Pg.

7.1.1 Operating - The WCS shall be capable of operating during and after being exposed to any feasible combination of environments specified in a, b, c, and d, and shall be capable of operating after being exposed to any feasible combination of environments specified in e, f, g, and i. The WCS is not required to operate after being exposed to crash safety environments.

a. Temperature

Atmospheric	Minimum: 65F	
	Maximum: 90F	R17
Structural	Minimum: 61F	
	Maximum: 120F	

b. Pressure

Cabin	Maximum: 16.0 psia	R18
	Minimum: 8.0 psia	
	Rate of Chg. 1.0 psi/min	
	Oxygen Partial Pressure Max: 3.45 psia	
Overboard Pressure	Minimum: 10^{-10} Torr	
	Atmosphere Diluent - Nitrogen	

c. Relative Humidity — Maximum: 85 percent relative humidity at 65 F dry bulb, 17 percent at 90 F dry bulb

d. Salinity — One percent by weight

e. Lightning — As specified in MF0004-02, Indirect

f. Acceleration — Plus or minus 5.0 g

g. Vibration

Mission Phase:	
Random vibration occurs at liftoff transonic and q_{max}	Acceleration spectral density increasing at the rate of plus 6 dB/octave from 20 to 150 Hz; constant at .03 g^2/Hz from 150 to 1000 Hz; decreasing at the rate of minus 6 dB/octave from 1000 to 2000 Hz. The vibration occurs for a duration of 48 minutes per axis.

Ref. Doc., Pg.

Sinusoidal vibration results from wind gusts, engine start and shutdown, staging and landing. — Sweeps 5 to 35 Hz at one octave per minute at .25 g's peak.

h. Crash Safety

gx	gy + Right	gz + Up	Ref. Doc., Pg.
+20	±3.3	+10.0 - 4.4	R18

There shall be no failure of the mounting attachment, and the equipment shall remain in place and not create a hazard.

i. Shock

Landing — Rectangular pulses of the following peak accelerations, time durations, and numbers of applications in the vertical/up direction during landing:

Acceleration (g peak)	Duration (Milliseconds)	Application	Ref. Doc., Pg.
0.23	170	22	
0.28	280	37	
0.35	330	32	
0.43	360	20	
0.56	350	9	
0.72	320	4	
1.50	260	1	R19

7.2 Ferry Flight Environment

The WCS shall be capable of meeting the performance requirements specified herein after exposure in a drained condition to any one or combination of the following environments: R19

a. Pressure — Maximum: 15.23 psia; Minimum: 3.25 psia

b. Temperature — Maximum: Plus 120F; Minimum: Minus 10F

Ref. Doc., Pg.

c. Humidity	Maximum: 100 percent relative Minimum 8 percent relative	

8.0 GROUND OPERATIONAL REQUIREMENTS

8.1 Transportation Environment

8.1.1 Transportation (Packaged) - The WCS shall be capable of meeting the operating performance requirments specified herein after exposure to the following transportation conditions when packaged in accordance with Section 10:

a. Temperature	Minimum ambient of minus 65F Maximum ambient of plus 150F Maximum compartment temperature while on ground of plus 190F for one hour and plus 150F for six hours.	
b. Pressure	Maximum of 15.23 pounds per square inch absolute (psia) (sea level) minimum of 3.28 psia (35,000 feet).	R16
c. Humidity	0 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost.	
d. Shock	Refer to 5.2.3 (prep. for delivery)	
e. Vibration	Refer to 5.2.3 (prep. for delivery)	

8.1.2 Ground Handling Loads (Unpackaged) - The WCS shall be capable of meeting the operating performance requirements specified herein after exposure to the following ground handling loads when unpackaged.

a. Handling Shock	Bench handling shock as specified in MIL-STD-810, Method 516.1, Procedure V.
b. Design Shock	20 g terminal sawtooth shock pulse of a 11 millisecond duration in each of 6 axes.

c. Hoisting Loads	2 g vertical within a plus or minus cone angle of 20 degrees.

8.2 Checkout Environment (WCS Installed)

The WCS shall be capable of operating as specified herein after exposure to environments specified as follows: R19

a. Pressure	
- Orbiter Operational Leak Check	Cabin pressure of 18.0 psia maximum at sea level
- Structural	30 psia
b. Temperature	
Cabin	35 F minimum, 120 F maximum
c. Humidity	8 to 100 percent relative humidity including conditions wherein condensation takes place in the form of water or frost.
d. Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight.

8.3 Storage Environment

The WCS shall be capable of meeting the operating performance requirements specified herein after exposure to the following storage conditions, when packaged in accordance with Section 5. R16

a. Temperature	Minus 23 F to plus 150 F
b. Humidity	0 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water of frost.
c. Pressure	Maximum of 15.23 psia (sea level), Minimum of 9.76 psia (10,000 feet).

		Ref. Doc., Pg.
d. Ozone	Surface maximum 3 to 6 parts per hundred million (phm); 60 phm for 1 to 3 hours in any 24 hour period. 100 phm at 35,000 feet.	
e. Fungus	As specified in MC999-0096.	R17
f. Sand and Dust	Equivalent to 140 mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 grams per cubic foot.	
g. Hail and Snow	Hail (nominal) diameter equals 0.30 inches with a fall velocity of 66 feet/second. Snow of 10.2 pounds per square foot.	
h. Salt Fog	Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 1.0 percent salt solution by weight.	
i. Rain	Maximum of 19 inches in 24 hour period including short period extremes of 4 inches in one hour.	
j. Solar Radiation	Solar radiation of 377.6 Btu/ft^2/ hr. for three hours in any 24 hour period.	

9. GENERAL REQUIREMENTS

This section contains general requirements as taken from the Rockwell Waste Collection Subsystem Procurement Specification No. MC282-0069 (Ref. R) and the MDAC Orbiter Workshop Centrifugal [Urine] Separator System CDR Data Package Report, March 31, 1971 (Ref. U). These requirements function as typical examples which may be tailored to fit the desired Orbiter WCS.

Ref. Doc., Pg.

9.1 Leakage and Venting
Refer to Reference R, Section 3.2.1.4 R8

9.2 Physical characteristics
Refer to Reference R, Sections 3.2.2.4 to 3.2.2.7 and 3.2.2.9 R10

9.3 Maintainability
Refer to Reference R, Section 3.2.4 R13

9.4 Transportability
Refer to Reference R, Section 3.2.6 R20

9.5 Design and Construction
Refer to Reference R, Section 3.3 to 3.3.6 R20

9.6 Notes
Refer to Reference R, Section 6 R40

10. PREPARATION FOR DELIVERY
Refer to Reference R, Section 5 and Reference U, Section 5.

11. QUALITY ASSURANCE

11.1 Reliability

11.1.1 General Requirement:
The WCS shall be reliable and include redundant electrical components and dual seals where practical. M5

11.1.2 Specific Requirements:
Refer to Reference R, Section 3.2.3

11.2 Development Testing

11.2.1 Development of Crew Operations Procedures, As Required

Ref. Do., Pg.

11.2.2 Demonstration of Crew Operational Procedures Using Mockup or Similar Hardware, As Required.

11.3 Qualification Tests

Refer to Reference R, Section 4 and Reference U, Section 4, for example Quality Assurance provisions.

12. REQUIREMENTS VERIFICATION MATRIX

This section contains an example Requirements Verification Matrix taken from Reference U, Page 51.

TABLE 1
REQUIREMENTS MATRIX
(SAMPLE)

VERIFICATION METHOD

I. TEST
- A. DEVELOPMENT
- B. QUALIFICATION
- C. PRODUCTION ACCEPTANCE

II. ASSESSMENT
1. SIMILARITY
2. ANALYSIS
3. INSPECTION
4. DEMONSTRATION

(EJ - ENGINEERING JUDGMENT)
(NA - NOT APPLICABLE)

REQUIREMENT					VERIFICATION									
						I						II		
ITEM				EJ OR NA		A	B	C				1	2	3	4
1	3.1			NA											
2	3.1.1			NA											
3	3.1.2			NA											
4	3.1.3			NA											
5	3.1.4			NA											
6	3.2			NA											
7	3.2.1												X		
8	3.3			NA											
9	3.3.1				4.3.2.1			X						X	
10	3.3.2				4.3.2.1			X						X	
11	3.3.2.1													X	
12	3.3.2.2													X	
13	3.3.3													X	
14	3.3.4				4.3.2.3			X					X		X
17	3.3.5												X		
18	3.4			NA											
19	3.4.1													X	
20	3.4.2			NA											
21	3.4.2.1												X		
22	3.4.2.2												X		
23	3.4.2.3												X		
24	3.4.3			NA											
25	3.4.3.1												X		
26	3.4.3.2				4.1.3.2.2 4.3.2.4	X		X							X
27	3.4 3.3				4.1.3.2.2	X									X
28	3.4.3.4				4.1.3.2.2	X									X
29	3.4.3.5				4.1.3.2.2	X		X					X	X	
30	3.5			NA	4.3.2.4										
31	3.5.1												X		
32	3.5.2			NA											
33	3.5.2.1												X		
34	3.5.2.2												X		

MCDONNELL DOUGLAS ASTRONAUTICS CO.
WESTERN DIVISION
HUNTINGTON BEACH, CALIFORNIA

SIZE	CODE IDENT NO.	DRAWING NO.
A	18355	1B87234
SCALE	REV A	SHEET 45